Sea contributions to spin 1/2 baryon structure, magnetic moments, and spin distribution

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Abstract

We treat the baryon as a composite system made out of a "core" of three quarks (as in the standard quark model) surrounded by a "sea" (of gluons and $q\bar{q}$-pairs) which is specified by its total quantum numbers like flavor, spin and color. Specifically, we assume the sea to be a flavor octet with spin 0 or 1 but no color. The general wavefunction for spin 1/2 baryons with such a sea component is given. Application to the magnetic moments is considered. Numerical analysis shows that a scalar (spin 0) sea with an admixture of a vector (spin 1) sea can provide very good fits to the magnetic moment data *using experimental errors*. Our best fit automatically gives g_A/g_V for neutron beta decay in agreement with data. This fit also gives reasonable values for the spin distributions of the proton and neutron.

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I. INTRODUCTION

Attempts to understand the static properties of hadrons in the framework of the standard quark model (SQM) have had limited success. The belief that valence quarks were responsible for the spin of the proton has been shattered by recent experiments [1].

The naive valence quark picture of hadron structure is a simplification which does not properly take into account the fact that quarks interact through color forces mediated by vector gluons. The existence of the quark-gluon interaction, in QCD, implies that a hadron should be viewed as consisting of valence quarks surrounded by a "sea" which contains gluons and virtual quark-antiquark ($q\bar{q}$) pairs. Deep inelastic lepton-nucleon scattering has shown the existence of a sea component and its importance for nucleon structure functions. It is thus necessary to understand how this sea contributes to the baryon spin and other low energy properties.

Several authors [2–7] have studied the effect of the sea contributions on the hadron structure and the static properties of baryons. Some consider the sea as a single gluon or a $q\bar{q}$-pair. However the sea, in general, consists of any number of gluons and $q\bar{q}$-pairs. In this paper we "model" the general sea by its total quantum numbers (flavor, spin and color) which are such that the sea wave function when combined with the valence quark wave function gives the desired quantum numbers for the physical hadron. In particular, we explore the consequences of a "sea" with flavor and spin but no color [6,7] for the low energy properties of the spin 1/2 baryon octet ($p, n, \Lambda, \ldots$).

For simplicity, we consider a flavor octet sea with spin 0 and spin 1. The physical baryon wavefunction incorporating the sea is used to calculate the baryon magnetic moments, understanding of which is our primary motivation. We find that a scalar (spin 0) sea and a vector (spin 1) sea described by two and one parameters respectively gives a very good fits to the magnetic moment data. These fits give us numerical predictions for the spin distributions of the nucleons and g_A/g_V for neutron beta decay.

In Sec. II, we discuss the wavefunctions for the physical baryons constructed from the

valence quarks and our model for the sea. In Sec. III, we obtain the magnetic moments from the modified wavefunction and a general discussion of the results for them is given in Sec. IV. Sec. V gives the consequences of the fits for the spin distributions. Our fits automatically predict g_A/g_V; the axial vector weak decay constant for neutron beta decay. Use of this datum as a constraint on the fits is briefly discussed in Sec. VI. Sec. VII gives a summary and discussion.

II. SPIN 1/2 OCTET BARYON WAVEFUNCTIONS WITH SEA

For the lowest-lying baryons, in the SQM, the three valence quarks are taken to be in a relative S-wave states. The flavor-spin wavefunction of the three quarks is totally symmetric while the color wavefunction is totally antisymmetric to give a color singlet baryon. For the $SU(3)$ flavor octet spin 1/2 baryons we denote this SQM or q^3 wavefunction by $\tilde{B}(\mathbf{8}, 1/2)$, the argument 1/2 refers to spin. These $J^P = \frac{1}{2}^+$ states are denoted by $\tilde{p}$, $\tilde{\Sigma}^+$, etc.

Representing the baryons by this wavefunction is at best a first-order approximation. In reality, since quarks interact, the baryons contain a "sea" of gluons and virtual $q\bar{q}$-pairs in addition to the valence quarks. The important question is how to take into account this general sea. We take this general sea to be described by wavefunctions which are specified by the total flavor, spin, and color quantum numbers of the sea. We picture the physical baryon as a q^3 "core" (described by SQM wavefunction $\tilde{B}(\mathbf{8}, 1/2)$) sorrounded by a sea.

The physical baryon octet states, denoted $B(\mathbf{8}, 1/2)$ are obtained by combining the "core" wavefunction $\tilde{B}(\mathbf{8}, 1/2)$ with the sea wavefunction with specific properties given below.

We assume the sea is a color singlet but has flavor and spin properties which when combined with those of the core baryons $\tilde{B}$ give the desired properties of the physical baryon B. We further assume that there is no relative orbital angular momentum between the core and the sea. Since both the physical and core baryon have $J^P = \frac{1}{2}^+$, this implies that the sea has even parity and spin 0 or 1. The spin 0 and 1 wavefunction for the sea are denoted by H_0 and H_1, respectively. We also refer to a spin 0 (1) sea as a scalar (vector) sea. For

$SU(3)$ flavor we assume the sea has a $SU(3)$ singlet component and an octet component described by wavefunctions $S(\mathbf{1})$ and $S(\mathbf{8})$, respectively. The color singlet sea in our model is thus described by the wavefunctions $S(\mathbf{1})H_0$, $S(\mathbf{1})H_1$, $S(\mathbf{8})H_0$, and $S(\mathbf{8})H_1$.

The $SU(3)$ symmetric and spinless sea component implicit in SQM is described by $S(\mathbf{1})H_0$. Such a color singlet sea would require at least two gluons or a $q\bar{q}$-pair. The sea described by the wavefunctions $S(\mathbf{1})H_1$, $S(\mathbf{8})H_0$, and $S(\mathbf{8})H_1$ require a minimum of one $q\bar{q}$-pair. The flavor and spin quantum numbers of the sea considered here are simple or minimal in the sense that they require only one $q\bar{q}$-pair. However, the color singlet sea described by the above wavefunctions can, in general, have any number of $q\bar{q}$-pairs and gluons consistent with its total flavor and spin quantum numbers.

We thus represent the physical baryon states as a superposition of different combinations of the core baryons with the sea wavefunctions specified above, namely

$$\begin{aligned} B(1/2) \sim\; & \tilde{B}(\mathbf{8},1/2)H_0S(\mathbf{1}) + \tilde{B}(\mathbf{8},1/2)H_0S(\mathbf{8}) \\ & +\tilde{B}(\mathbf{8},1/2)H_1S(\mathbf{1}) + \tilde{B}(\mathbf{8},1/2)H_1S(\mathbf{8}). \end{aligned} \tag{1}$$

The flavor and spin quantum numbers of the core baryons $\tilde{B}$ and the sea (in each term) combine to give the quantum numbers of the physical baryon B. The baryon B is thus part of the time just $\tilde{B}$ with an inert sea (first term in Eq. (1)) and part of the time $\tilde{B}$ plus sea with flavor and spin (last three terms in Eq. (1)).

Because the sea has flavor, Eq. (1) implies that a baryon $B(Y,I)$, with given isospin I and hypercharge Y, will contain core baryons $\tilde{B}$ with different I and Y thus the $B(Y,I)$ will have a very different quark content from the corresponding SQM-state $\tilde{B}(Y,I)$. For example, the physical proton p will contain terms involving $\tilde{p}$, $\tilde{\Lambda}$, $\tilde{\Sigma}^+$, etc. plus sea and have non-zero strange quark content unlike $\tilde{p}$ in SQM (see Eq. (7)). We now go on to formulate the baryon wavefunction more precisely.

The total flavor-spin wavefunction of a spin up ($\uparrow$) physical baryon which consists of 3 valence quarks and a sea component (as discussed above) can be written schematically as

$$B(1/2\uparrow) = \tilde{B}(\mathbf{8},1/2\uparrow)H_0S(\mathbf{1}) + b_{\mathbf{0}}\left[\tilde{B}(\mathbf{8},1/2)\otimes H_1\right]^{\uparrow} S(\mathbf{1})$$

$$
\begin{aligned}
&+\sum_N a(N)\left[\tilde{B}(\mathbf{8},1/2\uparrow)H_0\otimes S(\mathbf{8})\right]_N \\
&+\sum_N b(N)\left\{[\tilde{B}(\mathbf{8},1/2)\otimes H_1]^{\uparrow}\otimes S(\mathbf{8})\right\}_N .
\end{aligned} \tag{2}
$$

The normalization not indicated here is discussed later. The first term is the usual q^3-wavefunction of the SQM (with a trivial sea) and the second term (coefficent b_0) comes from spin-1 (vector) sea which combines with the spin 1/2 core baryon $\tilde{B}$ to a spin $1/2\uparrow$ state. So that,

$$
\left[\tilde{B}(\mathbf{8},1/2)\otimes H_1\right]^{\uparrow}=\sqrt{\frac{2}{3}}\tilde{B}(\mathbf{8},1/2\downarrow)H_{1,1}-\sqrt{\frac{1}{3}}\tilde{B}(\mathbf{8},1/2\uparrow)H_{1,0}. \tag{3}
$$

In both these terms the sea is a flavor singlet. The third (fourth) term in Eq. (2) contains a scalar (vector) sea which transforms as a flavor octet. The various $SU(3)$ flavor representations obtained from $\tilde{B}(\mathbf{8})\otimes S(\mathbf{8})$ are labelled by $N=\mathbf{1},\mathbf{8_F},\mathbf{8_D},\mathbf{10},\bar{\mathbf{10}},\mathbf{27}$. As it stands, Eq. (2) represents a spin $1/2\uparrow$ baryon which is not *a pure flavor octet* but has an admixture of other $SU(3)$ representations weighted by the unspecified constants $a(N)$ and $b(N)$. It will be a flavor octet if $a(N)=b(N)=0$ for $N=\mathbf{1},\mathbf{10},\bar{\mathbf{10}},\mathbf{27}$. The color wavefunctions have not been indicated as the three valence quarks in the core $\tilde{B}$ and the sea (by assumption) are in a color singlet state.

For our applications we adopt the phenomenological wavefunction given in Eq. (2), where the physical spin 1/2 baryons have admixtures of flavor $SU(3)$ determined by the coefficients $a(N)$ and $b(N)$, $N=\mathbf{1},\mathbf{10},\bar{\mathbf{10}},\mathbf{27}$. As we shall see, such a wavefunction which respects the isospin and hypercharge properties of the usual spin 1/2 baryon states is general enough to provide an excellent fit to the magnetic moments data. Surprisingingly, only 3 or 4 of the thirteen parameters in Eq. (2) are needed for this purpose. For the moment we discuss the general wavefunction in Eq. (2) as it is. Incidentally, such a wavefunction could arise in general since we know flavor is broken by mass terms in the QCD Lagrangian.

The sea isoespin multiplets contained in the octet $S(\mathbf{8})$ are denoted as

$$
(S_{\pi^+},S_{\pi^0},S_{\pi^-}),\qquad (S_{K^+},S_{K^0}),\qquad (S_{\bar{K}^0},S_{K^-}),\quad \text{and}\quad S_\eta. \tag{4}
$$

The suffix on the components label the isospin and hypercharge quantum numbers. Note, the familiar pseudoscalar mesons are used here as subscripts only to label the flavor quantum numbers of the sea states. All the components of $S(\mathbf{8})$ have $J^P = 0^+$ as mentioned earlier. For example, S_{π^+} has $I = 1, I_3 = 1$ and $Y = 0$; S_{K^-} has $I = 1/2, I_3 = -1/2$, and $Y = -1$; etc. These flavor quantum numbers when combined with those of the three valence quarks states $\tilde{B}$ will give the observed I, I_3, and Y for the physical states B. The flavor combinations in the third and fourth terms in Eq. (2) imply that the physical states $B(Y, I, I_3)$ are expressed as a sum of products of $\tilde{B}(Y, I, I_3)$ and the sea components $S(Y, I, I_3)$, weighted by some coefficients α_i which are linear combinations of the coefficients $a(N)$ and $b(N)$. Schematically, the flavor content of the third and fourth terms in Eq. (2) is of the form (suppressing I_3)

$$B(Y, I) = \sum_i \alpha_i(Y_1, Y_2, I_1, I_2) \left[\tilde{B}(Y_1, I_1)S(Y_2, I_2)\right]_i \tag{5}$$

where the sum is over all Y_i, I_i, $(i = 1, 2)$; such that: $Y = Y_1 + Y_2$ and $\mathbf{I} = \mathbf{I_1} + \mathbf{I_2}$. The flavor content of $B(Y, I, I_3)$ in terms of $\tilde{B}(Y, I, I_3)$ and sea components are given in Table I. The corresponding coefficients $\bar{\beta}_i$, β_i, etc. expressed in terms of the coefficients $a(N)$ (for the scalar sea) are recorded in Table II. In Table I we have denoted $\tilde{B}(Y, I, I_3)$ and $S(Y, I, I_3)$ by appropiate symbols, e.g., $\tilde{B}(1, 1, 1/2)$ by $\tilde{p}$, $S(0, 1, 1)$ by S_{π^+}, etc. Since the flavor content of the fourth term with vector sea is the same as for the scalar sea, the contribution of the fourth term in Eq. (2) to the physical baryon state can be obtained by using Eq. (3) and Tables I and II with the replacement $a(N) \to b(N)$ for $N = \mathbf{1}, \mathbf{8_F}, \mathbf{8_D}, \mathbf{10}, \mathbf{\bar{1}\bar{0}}, \mathbf{27}$. For later use, the coefficients obtained by changing $a(N) \to b(N)$ in $\bar{\beta}_i$, β_i, γ_i, and δ_i will be denoted by $\bar{\beta}'_i$, β'_i, γ'_i, and δ'_i. In Tables I and II for the reduction of $\tilde{B}(\mathbf{8}) \otimes S(\mathbf{8})$ into various $SU(3)$ representations we have followed the convention used by Carruthers [8].

The normalization of the physical baryons wavefunction in Eq. (2) can be obtained by using $\langle H_i | H_j \rangle = \delta_{ij}$, $\langle \tilde{B}(Y, I, I_3) | \tilde{B}(Y', I', I'_3) \rangle = \langle S(Y, I, I_3) | S(Y', I', I'_3) \rangle = \delta_{YY'}\delta_{II'}\delta_{I_3 I'_3}$. However, it should be noted that the normalization are different, in general, for each $B(Y, I)$ state. This is because not all $a(N)$ and $b(N)$ contribute to a given (Y, I)-multiplet as is clear

from Tables I and II. For example, $a(\mathbf{1})$ and $b(\mathbf{1})$ contribute only to Λ while $a(\mathbf{10})$ and $b(\mathbf{10})$ do not contribute to the nucleon states. Denoting by N_1, N_2, N_3, and N_4, the normalization constants for the (p, n), (Ξ^0, Ξ^-), $(\Sigma^\pm, \Sigma^0)$, and Λ isospin multiplets, one has

$$N_1^2 = N_0^2 + a^2(\bar{\mathbf{10}}) + b^2(\bar{\mathbf{10}}), \tag{6a}$$

$$N_2^2 = N_0^2 + a^2(\mathbf{10}) + b^2(\mathbf{10}), \tag{6b}$$

$$N_3^2 = N_0^2 + \sum_{N=\mathbf{10},\bar{\mathbf{10}}} [a^2(N) + b^2(N)], \tag{6c}$$

$$N_4^2 = N_0^2 + a^2(\mathbf{1}) + b^2(\mathbf{1}), \tag{6d}$$

where,

$$N_0^2 = 1 + b_0^2 + \sum_{N=\mathbf{8_D},\mathbf{8_F},\mathbf{27}} [a^2(N) + b^2(N)]. \tag{6e}$$

For example, using Tables I and II, and Eqs. (6), the physical spin-up proton state as given by Eq. (2) is

$$\begin{aligned} N_1|p\uparrow\rangle = {} & |\tilde{p}\uparrow\rangle H_0 S(\mathbf{1}) + b_0|(\tilde{p}\otimes H_1)^\uparrow\rangle S(\mathbf{1}) \\ & +\bar{\beta}_1|\tilde{p}\uparrow\rangle S_\eta + \bar{\beta}_2|\tilde{\Lambda}\uparrow\rangle S_{K^+} + \bar{\beta}_3|(\tilde{N}\uparrow S_\pi)_{1/2,1/2}\rangle + \bar{\beta}_4|(\tilde{\Sigma}\uparrow S_K)_{1/2,1/2}\rangle \\ & +\bar{\beta}'_1|(\tilde{p}\otimes H_1)^\uparrow\rangle S_\eta + \bar{\beta}'_2|(\tilde{\Lambda}\otimes H_1)^\uparrow\rangle S_{K^+} \\ & +\bar{\beta}'_3|((\tilde{N}\otimes H_1)^\uparrow S_\pi)_{1/2,1/2}\rangle + \bar{\beta}'_4|((\tilde{\Sigma}\otimes H_1)^\uparrow S_K)_{1/2,1/2}\rangle, \end{aligned} \tag{7}$$

where $(\tilde{B}\otimes H_1)^\uparrow$ are given in Eq. (3) and $\bar{\beta}'_1 = (3b(\mathbf{27}) - b(\mathbf{8_D}) + (b(\mathbf{8_F}) + b(\bar{\mathbf{10}}))/2)/\sqrt{20}$, and so on. Other baryon wavefunctions will have a similar structure. Also, $(\tilde{N}\uparrow S_\pi)_{1/2,1/2}$ $((\tilde{\Sigma}\uparrow S_K)_{1/2,1/2})$ stand for the $I = I_3 = 1/2$ combination of the $I = 1/2$ $\tilde{N}$ (S_K) and $I = 1$ S_π $(\tilde{\Sigma})$ multiplets.

For any operator $\hat{O}$ which depends only on quarks, the matrix elements are easily obtained using the ortogonality of the sea components. Clearly $\langle p\uparrow|\hat{O}|p\uparrow\rangle$ will be a linear

combination of the matrix elements $\langle \tilde{B} \uparrow |\hat{O}|\tilde{B}' \uparrow\rangle$ (known from SQM) with coefficients which depend on the coefficients in the wavefunction.

For applications, we need the quantities $(\Delta q)^B$, $q = u, d, s$; for each spin-up baryon B. These are defined as

$$(\Delta q)^B = n^B(q \uparrow) - n^B(q \downarrow) + n^B(\bar{q} \uparrow) - n^B(\bar{q} \downarrow), \tag{8}$$

where $n^B(q \uparrow)$ ($n^B(q \downarrow)$) are the number of spin-up (spin-down) quarks of flavor q in the spin-up baryon B. Also, $n^B(\bar{q} \uparrow)$ and $n^B(\bar{q} \downarrow)$ have a similar meaning for antiquarks. However, these are zero as there are no explicit antiquarks in the wavefunctions given by Eq. (2). The expressions for $(\Delta q)^B$ are given in Table III in terms of the coefficients b_0, $\bar{\beta}_i$, $\bar{\beta}'_i$, etc. Note that the terms involving b_0, $\bar{\beta}'_i$, β'_i, γ'_i, and δ'_i are multiplied by the factor $-1/3$ which comes from Eq. (3) on taking the matrix element of the operator $\hat{\Delta q}$. The expressions for $(\Delta q)^B$ reduce to the SQM values if there is no sea contribution, that is, $b_0 = 0$, $a(N) = b(N) = 0$, $N = \mathbf{1}, \mathbf{8_F}, \mathbf{8_D}, \mathbf{10}, \mathbf{\bar{1}\bar{0}}, \mathbf{27}$. Moreover, the total spin S_Z of a baryon is given by $S_Z^B = (1/2)\sum_q (\Delta q)^B + (\Delta(\text{sea}))^B$, where the second term represents the spin carried by the sea and depends solely on b_0 and $b(N)$'s, the coefficients determining the vector sea. For $S_Z^B = 1/2$, we expect $\sum_q (\Delta q)^B = 1$ for a purely scalar sea, i.e., when b_0 and all $b(N)$'s are zero. This is indeed true for each baryon as can be seen from Table III. There are three $(\Delta q)^B$ ($q = u, d, s$) for each (Y, I)-multiplet. These twelve quantities and $(\Delta q)^{\Sigma^0\Lambda}$ are given in terms of the thirteen parameters of Eq. (2) as our spin 1/2 baryons do not belong to a definite representation of $SU(3)$. To obtain a flavor octet physical baryon one restricts N to $\mathbf{8_F}$ and $\mathbf{8_D}$ in Eq. (2), that is, put $a(N) = b(N) = 0$ for $N = \mathbf{27}, \mathbf{10}, \mathbf{\bar{1}\bar{0}}, \mathbf{1}$, so that the twelve $(\Delta q)^B$ are given in terms of five parameters b_0, $a(N)$, $b(N)$ with $N = \mathbf{8_F}, \mathbf{8_D}$. It is clear, in this case, that our wavefunction provides a model for spin 1/2 baryons which is more general than the phenomenological model considered by some authors [9] recently to fit the baryon magnetic moments. These authors take the three quantities $(\Delta q)^p$ ($q = u, d, s$) as parameters to be determined from data but use flavor $SU(3)$ to express all the other $(\Delta q)^B$ in terms of the $(\Delta q)^p$. In our case the various $(\Delta q)^B$ are not simply related by flavor

$SU(3)$ because of the non-trivial flavor properties of the sea and thus provides an explicit and very different model for the baryons.

III. APPLICATION TO MAGNETIC MOMENTS

We assume the baryon magnetic moment operator $\hat{\mu}$ to be expressed solely in terms of quarks as is usual in the quark model. So that $\hat{\mu} = \sum_q (e_q/2m_q)\sigma_Z^q$ $(q = u, d, s)$. It is clear from Eq. (2) that $\mu_B = \langle B|\hat{\mu}|B\rangle$ will be a linear combination of $\mu_{\tilde{B}}$ and $\mu_{\tilde{\Sigma}^0\tilde{\Lambda}}$ weighted by the coefficients which depend on b_0, $a(N)$'s, and $b(N)$'s. The magnetic moments $\mu_{\tilde{B}}$ and the transition moment $\mu_{\tilde{\Sigma}^0\tilde{\Lambda}}$ (for the core baryons) are given in terms of the quark magnetic moments μ_q as per SQM. For example, $\mu_{\tilde{p}} = (4\mu_u - \mu_d)/3$, $\mu_{\tilde{\Lambda}} = \mu_s$, $\mu_{\tilde{\Sigma}^0\tilde{\Lambda}} = (\mu_u - \mu_d)/\sqrt{3}$, etc. Consequently, all the magnetic moments and the $\Sigma^0 \to \Lambda$ transition magnetic moment in our model can be written simply as

$$\mu_B = \sum_q (\Delta q)^B \mu_q, \qquad (q = u, d, s); \tag{9a}$$

$$\mu_{\Sigma^0\Lambda} = \sum_q (\Delta q)^{\Sigma^0\Lambda} \mu_q, \qquad (q = u, d); \tag{9b}$$

where the $(\Delta q)^B$ and $(\Delta q)^{\Sigma^0\Lambda}$ are given in Table III and $B = p, n, \Lambda, \ldots$.

A class of models [9] have been recently considered in which the magnetic moments were expressed in terms of μ_q and $(\Delta q)^p$ $(q = u, d, s)$ without giving an explicit wavefunction. Interestingly, Eqs. (9) have the same general structure except that here the twelve $(\Delta q)^B$ and $(\Delta q)^{\Sigma^0\Lambda}$ are not related but depend on thirteen parameters, namely, b_0 and six $b(N)$'s for the vector sea and the six $a(N)$'s for the scalar sea. Despite, our general wavefunction, the isospin sum rule [10]

$$\mu_{\Sigma^0} = \frac{1}{2}(\mu_{\Sigma^+} + \mu_{\Sigma^-}) \tag{10}$$

holds. This is because $\hat{\mu}$ transforms as $(I = 0) \oplus (I = 1)$ in isospin space and the wavefunction of Eq. (2) respects isospin thus giving $(\Delta q)^{\Sigma^0} = ((\Delta q)^{\Sigma^+} + (\Delta q)^{\Sigma^-})/2$ (see Table III).

Discussion of the case when physical baryons form a flavor octet. If we require the physical baryon states given by Eq. (2) to transform as an $SU(3)$ octet (i.e., put $a(N) = b(N) = 0,\ N = \mathbf{1}, \mathbf{10}, \bar{\mathbf{10}}, \mathbf{27}$) then the seven μ_B's and $\mu_{\Sigma^0\Lambda}$ depend non-linearly on five parameters (b_0, $b(\mathbf{8_F})$, $b(\mathbf{8_D})$, $a(\mathbf{8_F})$, and $a(\mathbf{8_D})$) of the wavefunction and the three μ_q's. Even so, three sum rules, namely

$$\mu_p - \mu_n = (\mu_{\Sigma^+} - \mu_{\Sigma^-}) - (\mu_{\Xi^0} - \mu_{\Xi^-}) \tag{11a}$$

$$((4.70589019 \pm 5 \times 10^{-7})\ \mu_N) \quad ((4.217 \pm 0.031)\ \mu_N) \tag{11b}$$

$$-6\mu_\Lambda = \mu_{\Sigma^+} + \mu_{\Sigma^-} - 2(\mu_p + \mu_n + \mu_{\Xi^0} + \mu_{\Xi^-}) \tag{12a}$$

$$((3.678 \pm 0.024)\ \mu_N) \quad ((3.340 \pm 0.039)\ \mu_N) \tag{12b}$$

$$2\sqrt{3}\mu_{\Sigma^0\Lambda} = 2(\mu_p - \mu_n) - (\mu_{\Sigma^+} - \mu_{\Sigma^-}) \tag{13a}$$

$$((5.577 \pm 0.277)\ \mu_N) \quad ((5.794 \pm 0.027)\ \mu_N) \tag{13b}$$

emerge. These have been noted earlier in the context of other models [6,9]. The values of the two sides taken from data [11] are shown in parentheses. The reason these sum rules hold despite the number of parameters is because they are a consequence of flavor $SU(3)$ since baryons form a $SU(3)$ octet and $\hat{\mu}$ transforms as $\mathbf{1} \oplus \mathbf{8}$. However, as can be seen, the first two $SU(3)$ sum rules are not well satisfied experimentally. To avoid them one could modify the $SU(3)$ transformation properties of $\hat{\mu}$ or the baryons. A group-theoretic analysis with the most general $\hat{\mu}$ which would contribute to the magnetic moments of an octet was done by Dothan [12] over a decade ago. Such a $\hat{\mu}$ could arise from $SU(3)$ breaking effects. However, several authors [13] have considered models in which they modify the baryon wavefunction. In our approach, we keep $\hat{\mu}$ as given by the quark model but modify the baryon wavefunction by taking a sea with flavor and spin into account as in Sec. II.

SQM has three parameters μ_q ($q = u,\ d,\ s$) the quark magnetic moments in nuclear magnetons μ_N. A fit using experimental errors gives $\chi^2/\mathrm{DOF} = 1818/5$ with $\mu_u = 1.8517$,

$\mu_d = -0.9719$, $\mu_s = -0.7013$. These values for μ_q differ from the values given in Ref. [11], since there μ_p, μ_n, and μ_Λ are used as inputs.

The situation improves a little for a pure octet physical baryon with scalar and vector sea described by $a(\mathbf{8_F})$, $a(\mathbf{8_D})$, b_0, $b(\mathbf{8_F})$, and $b(\mathbf{8_D})$. These five sea parameters enter Eqs. (9) only through the three combinations given by $(\Delta q)^p$. Hence, the 3 sum rules in Eqs. (11)-(13). For *experimental errors* with μ_q also as parameters one obtains [1] $\chi^2/\mathrm{DOF} = 652/3$. Most of the contribution to χ^2 comes from a poor fit to μ_{Σ^+}, μ_{Σ^-}, and μ_{Ξ^0}. This is a clear indication that admixture of other $SU(3)$ representations in our wavefunction need to be considered.

As noted above, even with both scalar and vector sea present, the poorly satisfied $SU(3)$ sum rules Eqs. (11)-(13) will hold as long the physical baryon is restricted to be an octet. This means we must include $SU(3)$ breaking effects in the baryon wavefunction by considering non-zero $a(N)$ and or $b(N)$ with $N = \mathbf{1}, \mathbf{10}, \bar{\mathbf{1}}\mathbf{0}, \mathbf{27}$.

IV. RESULTS

In making our fits we have used *experimental errors* as given by Particle Data Group [11]. This is in contrast to many authors who use “theoretical errors” of the order of a few percent or more to fit the data. In actual fact the experimental errors are much smaller. Furthermore, we keep in mind that the constituent quark masses are $m_u,\ m_d \approx 300$MeV, and $m_s \approx 500$Mev, so we expect $\mu_u \cong -2\mu_d > 0$ and $\mu_s \cong 0.6\mu_d$. Current quark masses would give a very different numerical range for the ratios μ_u/μ_d and μ_s/μ_d. Also, if the core baryon contribution is dominant then the parameters determining the sea should be small compared to unity. Furthermore, for a dominantly $SU(3)$ octet physical baryon b_0, $a(\mathbf{8_F})$, $a(\mathbf{8_D})$, $b(\mathbf{8_F})$, and $b(\mathbf{8_D})$ should be larger than the other parameters in the wave function.

To get a feeling for how the sea contributes we did extensive and systematic numerical

[1] Due to the form of Eqs. (9) there are only five effective parameters [9].

analysis separately for the three cases: pure scalar (spin 0) sea, pure vector (spin 1) sea, and scalar plus vector sea. In all the fits, in addition to the sea parameters, μ_q were treated as parameters.

Scalar sea. In general, here there are six parameters $a(N)$'s, $N = \mathbf{1}, \mathbf{8_F}, \mathbf{8_D}, \mathbf{10}, \bar{\mathbf{10}}, \mathbf{27}$, in the wavefunction and the three μ_q's. These nine parameters provide a perfect fit with $\chi^2 = 1.5 \times 10^{-4}$. This clearly means that the scalar sea contribution modifies the values of $(\Delta q)^B$ in the right direction for a fit to the baryon magnetic moments. However, a seven parameter fit with $a(\mathbf{1}) = 0.0625$, $a(\mathbf{8_D}) = -0.1558$, $a(\mathbf{8_F}) = 0.1896$, $a(\mathbf{10}) = 0.4297$, and $\mu_u = 1.8589$, $\mu_d = -0.9988$, and $\mu_s = -0.6530$, provides an excellent fit with $\chi^2/\mathrm{DOF} = 0.838$. The μ_q (in units of μ_N) imply for the quark masses the values $m_u = 336.49$ MeV, $m_d = 313.12$ MeV, and $m_s = 478.94$ MeV, which are in accord with the constituent quark model. A noteworthy six parameter fit with $\chi^2/\mathrm{DOF} = 5.60/2$ is given by $a(\mathbf{8_D}) = -0.2262$, $a(\mathbf{8_F}) = 0.2776$, and $a(\mathbf{10}) = 0.4216$, with $\mu_u = 1.8669$, $\mu_d = -1.0256$, and $\mu_s = -0.6466$. The predictions of this six parameter fit are displayed in the "Scalar sea" column of Table IV.

Vector sea. With seven parameters (b_0 and six $b(N)$'s) in the wavefunction and the three μ_q's one can at best obtain a $\chi^2 = 34$ at the cost of unrealistic values of μ_q's or m_q's. Unlike for the scalar sea, the pure vector sea modification of the wavefunction is in the wrong direction. This is probably because the vector sea contributions to $(\Delta q)^B$'s has an overall opposite sign (see Table III) to that of the scalar sea contribution.

Scalar plus vector sea. All the parameters in the wavefunction of Eq. (2) do not play a significant role. In fact, we find that excellent fits are obtained by describing the scalar sea by only two parameters $a(\mathbf{8_F})$ and $a(\mathbf{10})$ and the vector sea by one parameter either b_0 or $b(\mathbf{8_F})$. Two fits to the magnetic moment data with six parameters only (3 for the sea and 3 μ_q's) are listed in "Case 1" and "Case 2" columns of Table IV. For easy reference the parameters of the fits in Table IV are given in Table V. Note that the values of the ratios $-\mu_u/2\mu_d \approx 0.95$ and $\mu_s/\mu_d \approx 0.63$ for Cases 1 and 2 are practically the same as for SQM fit of Ref. [11].

Case 1. The scalar sea is determined by $a(\mathbf{8_F}) = -0.1489$ and $a(\mathbf{10}) = 0.4983$, while the vector sea is described by the single parameter $b(\mathbf{8_F}) = 0.5089$. The values obtained for μ_q's are $\mu_u = 2.4550$, $\mu_d = -1.2824$, and $\mu_s = -0.8071$, implying $m_u = 254.79$ MeV, $m_d = 243.89$ MeV, and $m_s = 387.51$ MeV. The $\chi^2/\mathrm{DOF} = 1.43/2$.

Case 2. The scalar sea parameters are again $a(\mathbf{8_F})$ and $a(\mathbf{10})$ with values close to those of Case 1 while the vector sea is described by b_0 alone. One finds $a(\mathbf{8_F}) = -0.1466$, $a(\mathbf{10}) = 0.4932$, and $b_0 = 0.4779$, with $\mu_u = 2.4748$, $\mu_d = -1.3010$, and $\mu_s = -0.8249$. The $\chi^2/\mathrm{DOF} = 2.23/2$. The quark magnetic moments (masses) are slightly larger (smaller) than Case 1.

Comparison of the two fits reveals: (a) In both cases, the two parameters $a(\mathbf{8_F})$ and $a(\mathbf{10})$ describing the scalar sea have practically the same values. (b) Though, the vector sea is described by only one parameter its nature is very different in the two cases. In Case 1, the vector sea carries flavour (parameter $b(\mathbf{8_F})$) but in Case 2 it is flavourless (parameter b_0). (c) The $SU(3)$ breaking effects are solely due to the scalar sea parameter $a(\mathbf{10})$. Note that $a(\mathbf{10})$ contributes only to the wavefunction of the Σ's and Ξ's. Its inclusion dramatically improves the poor fit to $\mu_{\Sigma^\pm}$ and μ_{Ξ^0} obtained for an octet physical baryon as mentioned above. (d) In both cases the quark magnetic moments (masses) are larger (smaller) than the SQM values but the ratios are in accord with SQM. (e) It should be emphasized that the inclusion of more parameters to describe the sea improves the fit only marginally.

In summary, the inclusion of a scalar sea or scalar plus vector sea in the baryon give excellent fits to the spin 1/2 baryon magnetic moment data. We feel our six parameters fits using actual experimental errors are significant since most fits with four to five parameters invoke large "theoretical or notional errors" of a few percent to obtain reasonable χ^2-values. It is gratifying that with just one more parameter we can fit the actual experimental magnetic moment data and also are able to accomodate the EMC and neutron beta decay data (see Secs. V and VI).

The magnetic moment fits determine all the $(\Delta q)^B$ which in turn have implications for spin distrbutions and the $\Delta s = 0$ axial vector weak decay constant g_A/g_V. We consider

these for the nucleons and neutron beta decay where data are available.

V. SPIN DISTRIBUTIONS

The spin distribution for the proton and neutron (in terms of quarks) are given by

$$I_1^p \equiv \int_0^1 g_1^p(x)dx = \frac{1}{2}[\frac{4}{9}(\Delta u)^p + \frac{1}{9}(\Delta d)^p + \frac{1}{9}(\Delta s)^p], \tag{14a}$$

$$I_1^n \equiv \int_0^1 g_1^n(x)dx = \frac{1}{2}[\frac{4}{9}(\Delta d)^p + \frac{1}{9}(\Delta u)^p + \frac{1}{9}(\Delta s)^p]. \tag{14b}$$

The SQM values are $I_1^p = 5/18$ and $I_1^n = 0$ in disagreement with experiment [14,15] which gives $I_1^p = 0.126 \pm 0.018$ and $I_1^n = -0.08 \pm 0.06$. One must remark that the EMC experiment gives I_1^p for $\langle Q^2 \rangle = 10.7$ (Gev/c)^2 and this could be very different for the very low Q^2 result predicted by our model or SQM. Nevertheless, encouraged by the results of Sec. IV we look at the implication for $I_1^{p,n}$ using the magnetic moment fits for the scalar sea and Cases 1 and 2.

Scalar sea. For this fit $(\Delta u)^p = 1.3225$, $(\Delta d)^p = -0.3045$, and $(\Delta s)^p = -0.0180$, these give $I_1^p = 0.2760$ and $I_1^n = 0.0048$, very close to the SQM values. This is not surprising since for a pure scalar sea $\sum_q (\Delta q)^B = 1$ for each baryon independent of the number and values of the parameters describing such a sea, that is, the baryon spin is carried entirely by the constituent quarks.

The EMC experiment tells us that this is not so. It is clear that for better fits to $I_1^{p,n}$ a vector sea is required so that $\sum_q (\Delta q)^B \neq 1$, which is true for Cases 1 and 2.

Case 1. Here $(\Delta u)^p = 0.9990$, $(\Delta d)^p = -0.2602$, and $(\Delta s)^p = -0.0083$ giving $\sum_q (\Delta q)^p = 0.7305$. These give $I_1^p = 0.2071$, $I_1^n = -0.0028$, with $\chi^2 = 23$.

Case 2. Here $(\Delta u)^p = 0.9999$, $(\Delta d)^p = -0.2464$, and $(\Delta s)^p = 0.0029$ giving $\sum_q (\Delta q)^p = 0.7564$. These give $I_1^p = 0.2087$, $I_1^n = 0.0010$, with $\chi^2 = 25$.

It is clear that in both cases, quarks still carry a large fraction of the proton spin and $\sum_q (\Delta q)^p$ is not small enough to give good agreement for I_1^p.

Further combined fits to magnetic moments and EMC data with scalar and vector sea were attempted. A seven parameter fit yielded $\chi^2 = 1.83/3$, with $a(\mathbf{8_F}) = -0.26411$, $a(\mathbf{10}) = 0.74254$, $b(\mathbf{8_F}) = 0.70358$, and $b(\mathbf{8_D}) = 0.61006$ describing the sea, while $\mu_u = 3.4181$, $\mu_d = -1.5076$, and $\mu_s = -0.9250$. This fit yields $(\Delta u)^p = 0.6938$, $(\Delta d)^p = -0.2616$, and $(\Delta s)^p = -0.0292$ so that $\sum_q (\Delta q)^p = 0.4030$ only. This fit is not favoured as it gives a rather small value ($(\Delta u)^p - (\Delta d)^p = 0.9554$) for g_A/g_V for neutron decay discussed below.

An experiment to measure the spin structure function of the Λ has been proposed recently [15]. Quark model gives

$$I_1^\Lambda \equiv \int_0^1 g_1^\Lambda(x)dx = \frac{1}{2}[\frac{4}{9}(\Delta u)^\Lambda + \frac{1}{9}(\Delta d)^\Lambda + \frac{1}{9}(\Delta s)^\Lambda]. \tag{15}$$

In SQM, this reduces to 1/18 (= 0.056) since $(\Delta u)^\Lambda = (\Delta d)^\Lambda = 0$, and $(\Delta s)^\Lambda = 1$. For Case 1, $(\Delta u)^\Lambda = (\Delta d)^\Lambda = -0.0083$, and $(\Delta s)^\Lambda = 0.7472$ yielding the prediction $I_1^\Lambda = 0.0392$ which is lower than the SQM value.

VI. AXIAL VECTOR WEAK DECAY CONSTANT (g_A/g_V)

Our general physical baryon wavefunction in Eq. (2) respects isospin, so that the physical p and n form an isodoublet and thus gives that for neutron beta decay $n \rightarrow p + e^- + \bar{\nu}_e$

$$\frac{g_A}{g_V} = (\Delta u)^p - (\Delta d)^p. \tag{16}$$

This is a very accurately measured quantity with the value 1.2573 ± 0.0028. Of the fits to the magnetic moments alone it is gratifying that the fits of Case 1 and Case 2 automatically yield $g_A/g_V = 1.2592$ and $g_A/g_V = 1.2463$, respectively. This encouraged us to try a combined fit to the 11 pieces of data, viz. 8 magnetic moments, 2 spin distributions, and g_A/g_V. The fits are very similar to those of Cases 1 and 2. Of these, the best fit is practically the same as for Case 1 and differs from it only in fitting g_A/g_V more exactly and so is not displayed in Table IV. It gives a total χ^2/DOF = 23.2/5, where $I_1^{p,n}$ contribute about 21.8 to the χ^2 (which is also true for Case 1).

VII. SUMMARY

In summary, we have considered the physical spin 1/2 low-lying baryons to be formed out of "core" baryons (described by the q^3-wavefunction of SQM) and a color singlet "sea" which carries flavor and spin. This sea (which may contain arbitrary number of gluons and $q\bar{q}$-pairs) is specified only by its total flavor and spin quantum numbers. The most general wavefunction for the physical baryons for an octet sea with spin 0 and 1 was considered (Sec. II) which respected isospin and hypercharge (or strangeness). Owing to the flavor properties of the sea the nucleons can have a non-zero strange quark content (giving $(\Delta s)^p = (\Delta s)^n \neq 0$) through the strange core baryons. In this model the eight baryons no longer form an exact $SU(3)$ octet. The admixture of other flavor $SU(3)$ representations in the wavefunction is understood to represent broken $SU(3)$ effects. The parameters in the wavefunction describing the sea were determined by application to the baryon magnetic moment data, our primary objective. We found an extremely good fit, with six parameters, to this data *using available experimental errors* [11]. Results are summarized in Tables IV and V. Three of these parameters determined the sea contribution while the other three were μ_q's (or m_q's, $q = u, d, s$) the quark magnetic moments (masses). The sea was found to be dominantly scalar (spin 0) described by 2 parameters while the admixture of the vector sea contributed only one parameter. The modified baryon wavefunction including such a sea which provides a good fit to the magnetic moment data has only three parameters. As a by product, for Case 1, we found a very good prediction for g_A/g_V for $n \rightarrow p + e^- + \bar{\nu}_e$. The prediction for the spin distributions is in better agreement than SQM. Our results (see Case 1 our best fit in Table IV) suggest that the physical spin 1/2 "octet" baryons contain an admixture of primarily the **10** representation. Why $SU(3)$ breaking (which we have invoked through a flavor octet sea) induce these representations is a question for the future when one is able to calculate the parameters in the wavefunction of Eq. (2) reliably from quantum chromodynamics.

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TABLES

TABLE I. Contribution to the physical baryon state $B(Y,I,I_3)$ formed out of $\tilde{B}(Y,I,I_3)$ and flavor octet states $S(Y,I,I_3)$ (see third and fourth terms in Eq. (2)). The core baryon states $\tilde{B}$ denoted by $\tilde{p}$, $\tilde{n}$, etc. are the normal 3 valence quark states of SQM. The sea octet states are denoted by $S_{\pi^+}=S(0,1,1)$, etc. as in Eq. (4). Further, $(\tilde{N}S_\pi)_{I,I_3}$, $(\tilde{\Sigma}S_{\bar{K}})_{I,I_3}$, $(\tilde{\Sigma}S_\pi)_{I,I_3}$, ... stand for total I, I_3 *normalized* combinations of $\tilde{N}$ and S_π, etc. See Table II for the coefficients $\bar{\beta}_i$, β_i, γ_i, and δ_i.

$B(Y,I,I_3)$	$\tilde{B}(Y,I,I_3)$ and $S(Y,I,I_3)$
p	$\bar{\beta}_1\tilde{p}S_\eta+\bar{\beta}_2\tilde{\Lambda}S_{K^+}+\bar{\beta}_3(\tilde{N}S_\pi)_{1/2,1/2}+\bar{\beta}_4(\tilde{\Sigma}S_K)_{1/2,1/2}$
n	$\bar{\beta}_1\tilde{n}S_\eta+\bar{\beta}_2\tilde{\Lambda}S_{K^0}+\bar{\beta}_3(\tilde{N}S_\pi)_{1/2,-1/2}+\bar{\beta}_4(\tilde{\Sigma}S_K)_{1/2,-1/2}$
Ξ^0	$\beta_1\tilde{\Xi}^0S_\eta+\beta_2\tilde{\Lambda}S_{\bar{K}^0}+\beta_3(\tilde{\Xi}S_\pi)_{1/2,1/2}+\beta_4(\tilde{\Sigma}S_{\bar{K}})_{1/2,1/2}$
Ξ^-	$\beta_1\tilde{\Xi}^-S_\eta+\beta_2\tilde{\Lambda}S_{\bar{K}^-}+\beta_3(\tilde{\Xi}S_\pi)_{1/2,-1/2}+\beta_4(\tilde{\Sigma}S_{\bar{K}})_{1/2,-1/2}$
Σ^+	$\gamma_1\tilde{p}S_{\bar{K}^0}+\gamma_2\tilde{\Xi}^0S_{K^+}+\gamma_3\tilde{\Lambda}S_{\pi^+}+\gamma_4\tilde{\Sigma}^+S_\eta+\gamma_5(\tilde{\Sigma}S_\pi)_{1,1}$
Σ^-	$\gamma_1\tilde{n}S_{K^-}+\gamma_2\tilde{\Xi}^-S_{K^0}+\gamma_3\tilde{\Lambda}S_{\pi^-}+\gamma_4\tilde{\Sigma}^-S_\eta+\gamma_5(\tilde{\Sigma}S_\pi)_{1,-1}$
Σ^0	$\gamma_1(\tilde{N}S_{\bar{K}})_{1,0}+\gamma_2(\tilde{\Xi}S_K)_{1,0}+\gamma_3\tilde{\Lambda}S_{\pi^0}+\gamma_4\tilde{\Sigma}^0S_\eta+\gamma_5(\tilde{\Sigma}S_\pi)_{1,0}$
Λ	$\delta_1(\tilde{N}S_{\bar{K}})_{0,0}+\delta_2(\tilde{\Xi}S_K)_{0,0}+\delta_3\tilde{\Lambda}S_\eta+\delta_4(\tilde{\Sigma}S_\pi)_{0,0}$

TABLE II. The coefficients $\bar{\beta}_i$, β_i, γ_i, and δ_i in Table I expressed in terms of the coefficients $a(N)$, $N = \mathbf{1}, \mathbf{8_F}, \mathbf{8_D}, \mathbf{10}, \mathbf{\bar{1}\bar{0}}, \mathbf{27}$, in the 3rd term (from scalar sea) in Eq. (2). The corresponding coefficients $\bar{\beta}'_i$, β'_i, γ'_i, and δ'_i determining the flavor of structure of 4th term in Eq. (2) can be obtained from $\bar{\beta}_i$, etc. by the replacement $a(N) \to b(N)$ (see text).

$\bar{\beta}_1 = \frac{1}{\sqrt{20}}(3a(\mathbf{27}) - a(\mathbf{8_D})) + \frac{1}{2}(a(\mathbf{8_F}) + a(\mathbf{\bar{1}\bar{0}}))$	$\beta_1 = \frac{1}{\sqrt{20}}(3a(\mathbf{27}) - a(\mathbf{8_D})) - \frac{1}{2}(a(\mathbf{8_F}) - a(\mathbf{10}))$
$\bar{\beta}_2 = \frac{1}{\sqrt{20}}(3a(\mathbf{27}) - a(\mathbf{8_D})) - \frac{1}{2}(a(\mathbf{8_F}) + a(\mathbf{\bar{1}\bar{0}}))$	$\beta_2 = \frac{1}{\sqrt{20}}(3a(\mathbf{27}) - a(\mathbf{8_D})) + \frac{1}{2}(a(\mathbf{8_F}) - a(\mathbf{10}))$
$\bar{\beta}_3 = \frac{1}{\sqrt{20}}(a(\mathbf{27}) + 3a(\mathbf{8_D})) + \frac{1}{2}(a(\mathbf{8_F}) - a(\mathbf{\bar{1}\bar{0}}))$	$\beta_3 = -\frac{1}{\sqrt{20}}(a(\mathbf{27}) + 3a(\mathbf{8_D})) + \frac{1}{2}(a(\mathbf{8_F}) + a(\mathbf{10}))$
$\bar{\beta}_4 = -\frac{1}{\sqrt{20}}(a(\mathbf{27}) + 3a(\mathbf{8_D})) + \frac{1}{2}(a(\mathbf{8_F}) - a(\mathbf{\bar{1}\bar{0}}))$	$\beta_4 = \frac{1}{\sqrt{20}}(a(\mathbf{27}) + 3a(\mathbf{8_D})) + \frac{1}{2}(a(\mathbf{8_F}) + a(\mathbf{10}))$
$\gamma_1 = \frac{1}{\sqrt{10}}(\sqrt{2}a(\mathbf{27}) - \sqrt{3}a(\mathbf{8_D})) + \frac{1}{\sqrt{6}}(a(\mathbf{8_F}) - a(\mathbf{10}) + a(\mathbf{\bar{1}\bar{0}}))$	$\delta_1 = \frac{1}{\sqrt{20}}(\sqrt{3}a(\mathbf{27}) + \sqrt{2}a(\mathbf{8_D})) + \frac{1}{2}(\sqrt{2}a(\mathbf{8_F}) + a(\mathbf{1}))$
$\gamma_2 = \frac{1}{\sqrt{10}}(\sqrt{2}a(\mathbf{27}) - \sqrt{3}a(\mathbf{8_D})) - \frac{1}{\sqrt{6}}(a(\mathbf{8_F}) - a(\mathbf{10}) + a(\mathbf{\bar{1}\bar{0}}))$	$\delta_2 = -\frac{1}{\sqrt{20}}(\sqrt{3}a(\mathbf{27}) + \sqrt{2}a(\mathbf{8_D})) + \frac{1}{2}(\sqrt{2}a(\mathbf{8_F}) - a(\mathbf{1}))$
$\gamma_3 = \frac{1}{\sqrt{10}}(\sqrt{3}a(\mathbf{27}) + \sqrt{2}a(\mathbf{8_D})) - \frac{1}{2}(a(\mathbf{10}) + a(\mathbf{\bar{1}\bar{0}}))$	$\delta_3 = \frac{3\sqrt{3}}{\sqrt{40}}a(\mathbf{27}) - \frac{1}{\sqrt{5}}a(\mathbf{8_D}) - \frac{\sqrt{2}}{4}a(\mathbf{1})$
$\gamma_4 = \frac{1}{\sqrt{10}}(\sqrt{3}a(\mathbf{27}) + \sqrt{2}a(\mathbf{8_D})) + \frac{1}{2}(a(\mathbf{10}) + a(\mathbf{\bar{1}\bar{0}}))$	$\delta_4 = -\frac{1}{\sqrt{40}}a(\mathbf{27}) - \sqrt{\frac{3}{5}}a(\mathbf{8_D}) + \frac{\sqrt{6}}{4}a(\mathbf{1})$
$\gamma_5 = \frac{1}{\sqrt{6}}(2a(\mathbf{8_F}) + a(\mathbf{10}) - a(\mathbf{\bar{1}\bar{0}}))$	

TABLE III. $(\Delta q)^B$ defined in Eq. (8) for physical baryon B given by general wavefunction in Eq. (2). The normalizations N_1, N_2, N_3, and N_4 are given in Eqs. (6). The $(\Delta q)^{\Sigma^0\Lambda}$ for the $\Sigma^0 \to \Lambda$ transition magnetic moment is also given.

$$(\Delta u)^p = \frac{1}{3N_1^2}[4(1-\tfrac{1}{3}b_0^2) + (4\bar{\beta}_1^2 + \tfrac{2}{3}\bar{\beta}_3^2 + \tfrac{10}{3}\bar{\beta}_4^2 - 2\bar{\beta}_2\bar{\beta}_4) - \tfrac{1}{3}(\bar{\beta}_i \to \bar{\beta'}_i)]$$

$$(\Delta d)^p = \frac{1}{3N_1^2}[-(1-\tfrac{1}{3}b_0^2) + (-\bar{\beta}_1^2 + \tfrac{7}{3}\bar{\beta}_3^2 + \tfrac{2}{3}\bar{\beta}_4^2 + 2\bar{\beta}_2\bar{\beta}_4) - \tfrac{1}{3}(\bar{\beta}_i \to \bar{\beta'}_i)] \qquad (\Delta s)^p = \frac{1}{3N_1^2}[(3\bar{\beta}_2^2 - \bar{\beta}_4^2) - \tfrac{1}{3}(\bar{\beta}_i \to \bar{\beta'}_i)]$$

$$(\Delta u)^n = (\Delta d)^p \qquad (\Delta d)^n = (\Delta u)^p \qquad (\Delta s)^n = (\Delta s)^p$$

$$(\Delta u)^{\Xi^0} = \frac{1}{3N_2^2}[-(1-\tfrac{1}{3}b_0^2) + (-\beta_1^2 - \tfrac{1}{3}\beta_3^2 + \tfrac{10}{3}\beta_4^2 - 2\beta_2\beta_4) - \tfrac{1}{3}(\beta_i \to \beta_i')]$$

$$(\Delta d)^{\Xi^0} = \frac{1}{3N_2^2}[(-\tfrac{2}{3}\beta_3^2 + \tfrac{2}{3}\beta_4^2 + 2\beta_2\beta_4) - \tfrac{1}{3}(\beta_i \to \beta_i')] \qquad (\Delta s)^{\Xi^0} = \frac{1}{3N_2^2}[4(1-\tfrac{1}{3}b_0^2) + (4\beta_1^2 + 3\beta_2^2 + 4\beta_3^2 - \beta_4^2) - \tfrac{1}{3}(\beta_i \to \beta_i')]$$

$$(\Delta u)^{\Xi^-} = (\Delta d)^{\Xi^0} \qquad (\Delta d)^{\Xi^-} = (\Delta u)^{\Xi^0} \qquad (\Delta s)^{\Xi^-} = (\Delta s)^{\Xi^0}$$

$$(\Delta u)^{\Sigma^+} = \frac{1}{3N_3^2}[4(1-\tfrac{1}{3}b_0^2) + (4\gamma_1^2 - \gamma_2^2 + 4\gamma_4^2 + 3\gamma_5^2 - \sqrt{6}\gamma_3\gamma_5) - \tfrac{1}{3}(\gamma_i \to \gamma_i')]$$

$$(\Delta d)^{\Sigma^+} = \frac{1}{3N_3^2}[(-\gamma_1^2 + \gamma_5^2 + \sqrt{6}\gamma_3\gamma_5) - \tfrac{1}{3}(\gamma_i \to \gamma_i')] \qquad (\Delta s)^{\Sigma^+} = \frac{1}{3N_3^2}[-(1-\tfrac{1}{3}b_0^2) + (4\gamma_2^2 + 3\gamma_3^2 - \gamma_4^2 - \gamma_5^2) - \tfrac{1}{3}(\gamma_i \to \gamma_i')]$$

$$(\Delta u)^{\Sigma^-} = (\Delta d)^{\Sigma^+} \qquad (\Delta d)^{\Sigma^-} = (\Delta u)^{\Sigma^+} \qquad (\Delta s)^{\Sigma^-} = (\Delta s)^{\Sigma^+}$$

$$(\Delta u)^{\Sigma^0} = \tfrac{1}{2}[(\Delta u)^{\Sigma^+} + (\Delta u)^{\Sigma^-}] \qquad (\Delta d)^{\Sigma^0} = (\Delta u)^{\Sigma^0} \qquad (\Delta s)^{\Sigma^0} = (\Delta s)^{\Sigma^+}$$

$$(\Delta u)^{\Lambda} = \frac{1}{3N_4^2}[(\tfrac{3}{2}\delta_1^2 - \tfrac{1}{2}\delta_2^2 + 2\delta_4^2) - \tfrac{1}{3}(\delta_i \to \delta_i')]$$

$$(\Delta d)^{\Lambda} = (\Delta u)^{\Lambda} \qquad (\Delta s)^{\Lambda} = \frac{1}{3N_4^2}[3(1-\tfrac{1}{3}b_0^2) + (4\delta_2^2 + 3\delta_3^2 - \delta_4^2) - \tfrac{1}{3}(\delta_i \to \delta_i')]$$

$$(\Delta u)^{\Sigma^0\Lambda} = \frac{1}{N_3N_4}[\tfrac{1}{\sqrt{3}}(1-\tfrac{1}{3}b_0^2) + (\tfrac{1}{\sqrt{3}}\gamma_4\delta_3 - \tfrac{1}{3}\gamma_3\delta_4 + \tfrac{5}{6}\gamma_1\delta_1 - \tfrac{1}{6}\gamma_2\delta_2 + \tfrac{4}{3\sqrt{6}}\gamma_5\delta_4) - \tfrac{1}{3}(\gamma_i, \delta_i \to \gamma_i', \delta_i')]$$

$$(\Delta d)^{\Sigma^0\Lambda} = -(\Delta u)^{\Sigma^0\Lambda} \qquad (\Delta s)^{\Sigma^0\Lambda} = 0$$

TABLE IV. Results for the baryon magnetic moments (in N.M.), spin distributions, and g_A/g_V along with available data and SQM fit for comparison. In each case, the χ^2/DOF quoted is for the fit to magnetic moment data alone. Last three columns give our fits using six parameters: 3 μ_q's and 3 parameters for the sea. Column 4 gives the results for a pure scalar sea while the last two columns give those for scalar sea (2 parameters) plus vector sea (1 parameter) labelled as Cases 1 and 2. The predictions for $I_1^{p,n}$ and g_A/g_V (from the fit to magnetic moments) is given in the last three rows. Case 1 gives the best fit. For details see text and Table V where the fit parameters are compared.

Baryon	Data	SQM	Scalar sea	Case 1	Case 2
p	$2.79284739 \pm 6 \times 10^{-8}$	2.7928	2.7928	2.7928	2.7928
n	$-1.9130428 \pm 5 \times 10^{-7}$	-1.9130	-1.9130	-1.9130	-1.9130
Λ	-0.613 ± 0.004	-0.701	-0.616	-0.613	-0.616
Σ^+	2.458 ± 0.010	2.703	2.456	2.457	2.459
Σ^0	——	0.8203	0.6238	0.6371	0.6362
Σ^-	-1.160 ± 0.025	-1.062	-1.208	-1.183	-1.186
Ξ^0	-1.250 ± 0.014	-1.552	-1.248	-1.249	-1.253
Ξ^-	-0.6507 ± 0.0025	-0.6111	-0.6500	-0.6504	-0.6507
$\lvert\Sigma^0 \to \Lambda\rvert$	1.61 ± 0.08	1.63	1.52	1.55	1.55
χ^2/DOF	——	1818/5	5.60/2	1.43/2	2.23/2
I_1^p	0.126 ± 0.018	0.278	0.276	0.207	0.209
I_1^n	-0.08 ± 0.06	0	0.005	-0.003	0.001
g_A/g_V	1.2573 ± 0.0028	1.6667	1.6270	1.2592	1.2463

TABLE V. Comparison of the 6 parameters for various fits to the magnetic moments and the values of $(\Delta q)^p$ obtained. The SQM values for μ_q and $(\Delta q)^p$ are also given. The parameters $a(\mathbf{8_D})$, $a(\mathbf{8_F})$, and $a(\mathbf{10})$ refer to a scalar sea while b_0 and $b(\mathbf{8_F})$ refer to a vector sea. See text for details and Table IV for results.

	SQM	Scalar sea	Scalar plus vector sea	
			Case 1	Case 2
μ_u	1.8517	1.8669	2.4550	2.4748
μ_d	−0.9719	−1.0256	−1.2824	−1.3010
μ_s	−0.7013	−0.6466	−0.8071	−0.8249
$a(\mathbf{8_D})$	——	−0.2262	——	——
$a(\mathbf{8_F})$	——	0.2776	−0.1489	−0.1466
$a(\mathbf{10})$	——	0.4216	0.4983	0.4932
$b(\mathbf{8_F})$	——	——	0.5089	——
b_0	——	——	——	0.4779
$(\Delta u)^p$	4/3	1.3225	0.9990	0.9999
$(\Delta d)^p$	−1/3	−0.3045	−0.2602	−0.2464
$(\Delta s)^p$	0	−0.0180	−0.0083	0.0029